THE PISTACHIO TREE; BOTANY AND PHYSIOLOGY AND FACTORS THAT AFFECT YIELD

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The pistachio is the single most successful plant introduction to the United States in the twentieth century.

ORIGIN AND HISTORY

The pistachio is native to western Asia and Asia Minor, where it is still found growing wild in numerous hot, dry locations in Lebanon, Palestine, Syria, Iran, Iraq, India, Southern Europe and the desert countries of Asia and Africa. It was introduced to Europe at the beginning of the Christian era. The first pistachio introductions to the United States were by the USDA plant exploration service in 1890. The first California introductions were planted at the Plant Introduction Station in Chico, California in the Northern Sacramento Valley in 1904.

BOTANICAL CLASSIFICATION

The pistachio of commerce is the only edible species among the 11 species in the genus *Pistacia*; all are characterized by their ability to exude turpentine or mastic. Several are referred to as pistachios, but the name is generally reserved for the edible nut of commerce. Its Latin name is *Pistacia vera* L. A member of the family Anacardiaceae, it is related to the cashew, mango, poison ivy and oak, pepper tree and sumac.

The tree has a pinnately compound leaf. Each leaf subtends a single axillary bud. Most of these lateral axillary buds differentiate into inflorescence primordia and produce a nut-bearing rachis the following year; thus, pistachios bear laterally on one-year-old wood. Botanically, pistachio nuts are drupes, the same classification for almonds, peaches, apricots, cherries and plums. All drupes consist of three parts; an exocarp, a fleshy mesocarp and an endocarp that encloses a seed. The difference lies in the edible portion. In pistachios and almonds the seed is consumed, rather than the mesocarp as in stone fruit.

The pistachio tree is dioecious (i.e. two houses"), meaning the male flowers are borne on one tree and the female flowers on another. Therefore, both male and female trees are required to produce nuts. The female flower is apetalous (no petals) and has no nectarines, thus does not attract bees. The pollen is spread by wind. The pistachio tree is deciduous, so it loses its leaves in the fall and remains dormant through the winter.

The rooting habit of the tree is classified as a phreatophyte. Phreatophytes have extensive root systems allowing them to mine the soil deeply. Thus, pistachios are adapted to survive long periods of drought.

Pistachios are characterized by a long juvenile period, typically bearing few nuts before five years of age. They achieve full bearing between 10 to 12 years of age. The tree has an upright growth habit characterized by a strong apical dominance and a lack of lateral vegetative buds in older trees. These characteristics have strong implications for young tree training, mature tree pruning and rejuvenation of fruiting wood in older trees.

CLIMATIC REQUIREMENTS

Areas suitable for pistachio production have long, hot, dry summers and moderate winters. Pistachios grow best in areas with 2200-2800 heat units.

$$\text{Heat Units} = \left[\frac{\text{Mean Monthly Tmax} + \text{Mean Monthly Tmin}}{2} \right] \times \text{Number of days In month (April-Oct)}$$

Generally, pistachios should not be planted above 2500 feet where summer heat is usually insufficient for complete kernel development. Elevations of 200 to 800 feet have proven ideal in the central California valleys. Late spring rains, frosts, and strong desiccating winds interfere with pollination. High humidity through the growing season promotes fungal diseases that subsequently overwinter on both male and female trees and reinoculate the tree the following season. Strong winds are generally detrimental to young tree training.

Historically, for both the female Kerman and male Peters to produce good, even, timely budbreak, normal inflorescences, viable pollen, good fruit set, and normal vegetative growth, pistachios in California have required at least 900 winter chilling hours below 45°F (7.2°C). When cumulative hours below 45°F (7.2°C) have fallen to 670, as they did in 1977-78, the bloom and foliation have been irregular and delayed, leaves deformed and yield reduced.

Pistachios can be successfully grown on a number of soil types. In California, the Pacheco sandy loams of the southwest San Joaquin Valley produce the best yields. In areas with shallow hardpan soils, tree size and productivity are limited. The tree grows best on well-drained soils and is intolerant of saturated conditions. It appears to tolerate alkalinity and salinity well. The topic of soils and their modification for pistachio production is discussed later, in the chapter 4, "Site Evaluation and Soil Modification" in this manual.

As stated earlier, pistachios are phreatophytes and as such can survive harsh climates without irrigation. Also, the stomata on their leaves are somewhat less sensitive to desiccating conditions than stomata on many other trees. Therefore, pistachios can transpire a great deal of water under San Joaquin Valley conditions. The result is a tree that is adapted for survival, but for economic production, adequate irrigation is necessary. Irrigation of pistachios, how much, when, and the method of application, have important implications for production. Pistachio irrigation has a significant impact on young tree development, soil-borne and aerial diseases, crop yield and quality (both current and subsequent years) and tree growth. Irrigation and its impact on these processes is discussed in chapter 13, "Tree Water Requirements and Regulated Deficit Irrigation" in this manual.

SEASONAL PHENOLOGY

The lateral axillary inflorescence buds on one-year-old wood begin to swell in late March. Within the first two weeks of April, the 100 to 300 flowers per paniculate rachis are pollinated and set. Throughout the balance of April and May the nut shell (endocarp), but not the nutmeat (seed), enlarges. Through this period the nut shell is soft and vulnerable to insect attack and the splitting that appears to be a result of rain. In June the nut shell hardens, and from late June through early August the nutmeat enlarges until it fills the shell. Through late August and September the nut ripens, the radial suture around the shell's long circumference splits, the hull degrades, and abscission of the individual nut from the rachis commences.

Shoot growth is simultaneous with shell growth. Growth begins in late April and concludes in late May. The new extension growth produces pinnately compound leaves with lateral inflorescence buds in the axils and, generally, a single apical vegetative bud. The buds differentiate throughout April, May and June, become quiescent in July, August and September, and resume differentiation in October. Sometimes there is an additional flush of shoot growth in late June. This growth produces primarily vegetative lateral buds as opposed to the inflorescence buds produced by the spring flush. In August, leaves distal to heavy fruit clusters often display a marked depletion and senescence. Most leaves drop by

the end of November, and the tree remains dormant through the following March. As the trees mature, their strong apical dominance becomes more marked.

PHYSIOLOGICAL PROBLEMS

Pistachios display three physiological conditions. The first is alternate bearing; an annual fluctuation of large crops with poor crops. The second is the production of blank, or unfilled nuts. The third is nonsplit nuts, nuts that fail to split along the lateral nut suture. All three phenomena appear to be ultimately related to crop load and are therefore probably related to carbohydrate competition. Thus far, little is known about the specific mechanism of each, though correlation with crop load is apparent in each case.

Alternate bearing

As stated earlier, pistachios bear laterally on one-year-old wood. As the trees age, they develop an alternate bearing pattern with increasingly large and small crops. Though the specific mechanism of this phenomenon has not been defined, evidence suggests that it is a problem of carbohydrate competition, perhaps mediated by growth regulator signals. During the period of nut fill in July, the fruit buds distal to fruit clusters die and abscise. The heavier the currently borne crop, the greater the subtending bud abscission. Thus, following a heavy crop year, an individual branch may bear no fruit. Attempts to alleviate the cycle by nutritional and growth regulator sprays have not been successful. However, some success in damping the swing has been achieved with rejuvenation pruning of older trees. Currently, pruning appears to be the only method available to mitigate alternate bearing. Alternate bearing has not been demonstrated to harmful to the tree and may therefore only be a marketing problem. Alternate bearing is not unique to pistachio trees. Several types of fruit trees alternate bear. However, only pistachios appear to possess the phenomenon of premature bud abscission as the mechanism that produces alternate bearing.

INTRODUCTION TO BLANK AND NONSPLIT NUTS

Pistachio fruits consist of a nutmeat (kernel) enclosed in a thin, hard shell (endocarp) surrounded by a fleshy hull (mesocarp and exocarp). The fruit grows from the pistil of the female flower. The pistil has a single ovary at its base. The ovary forms the fruit wall that includes the shell and the hull. Within the ovary is a single ovule. The ovule, which contains the female germ cell (egg), will develop into the edible kernel of the nut. Extending from the ovary is a three-part style. Each of the three parts of the style terminates in a stigma. As the flower opens, these stigma surfaces become receptive to pollen.

Fruit set typically follows successful pollination. Pollen is released from staminate flowers on male trees and is carried by air currents to stigmas of the pistillate flowers. When a pollen grain lands on a receptive stigma surface, it germinates to form a pollen tube. The pollen tube is an elongate cell that grows through sigma and style tissue to the basal ovary and into the ovule. As it does so, it carries male germ cells to the egg cell. Many pollen tubes germinate and grow through the style, but only one successfully reaches the ovule. That pollen tube enters the ovule and releases its contents. Fertilization involves the fusion of a male germ cell with the egg cell. Thus, the reproductive process leading to fruit set in pistachio can be seen in three parts: pollination, involving the transfer of pollen to the stigma; pollen tube growth, where the male germ cells are transferred through the stigma and style to the ovule, and fertilization, the fusion of the male and female germ cells in the ovule.

The fusion of the male and female germ cells produces a single-celled zygote that eventually grows to form an embryonic plant. This embryonic plant comprises the kernel. This process begins slowly, however. The first division of the zygote does not occur for several weeks after flowering during which time the ovary grows to its final size. After ovary growth is complete, the kernel grows to fill it. This is an unusual pattern of growth, and the differential timing of pistachio ovary and

kernel development has implications for both blank nut production and shell splitting.

BLANK NUTS
Blank nuts result when there is fruit set and ovary growth, but the embryo fails to grow, leaving the nut shell empty or blank. Blanking can occur during two different phases of pistachio nut development, nut setting and nut filling. It can be affected by crop load and production practices.

Blanking during nut set
Chronologically, the first empty shells (blanks) are produced as a result of events that occur at the time of fruit set. This can occur under a set of circumstances where pollination occurs but fertilization fails either because pollen tubes do not complete growth to the ovule, or the ovule is not viable when the pollen tubes do arrive. Under this scenario, the stimulus of pollination and/or pollen tube growth is sufficient to induce fruit set, but the failure of successful fertilization means there is no embryo formed, so there is no kernel to fill the shell. This phenomenon of fruit set without fertilization is called parthenocarpy and is the basis for the production of several types of seedless fruits, including some seedless citrus varieties. Parthenocarpy is fairly common among plants, however, it normally is found in fruits that have many seeds rather than in single-seeded fruits such as the pistachio.

There is some experimental evidence that pollination-induced parthenocarpy is a potential mechanism leading to blank pistachio nuts. In one study, flowers were pollinated with pollen that had been exposed to a high dose of gamma radiation. The radiation treatment was at a threshold level that permitted pollen germination but inhibited full pollen tube growth. These experiments resulted in a high percentage of blank nuts. One explanation is that the pollination stimulus, which was not eliminated in the irradiated pollen, is sufficient to set the fruit, most likely by triggering a hormonally mediated signal that leads to fruit set. Research is currently underway to determine if this finding has implications in the field.

This form of blanking may be associated with poor boron nutrition. Boron is known to be involved in several important aspects of plant reproductive biology, including pollen tube growth and ovule longevity, both of which may have a role in pollination-induced parthenocarpy. Research has demonstrated boron leaf levels below 120 ppm dry weight (August leaf sample) are associated with an increased percentage of blank nuts at harvest.

Blanking during nut fill
Blanks may also develop in July during kernel enlargement, when a certain percentage of the fertilized embryos fail to enlarge to fill the shell. It is not known what determines the percentage of nuts filled, but it is suspected the tree's stored carbohydrate capacity initially determines the percentage of filled nuts. This theory is corroborated by demonstrations that thinning a cluster prior to nut growth will result in a higher *percentage* of filled nuts on the thinned cluster. However, the thinned and unthinned clusters have virtually the same *absolute number* of filled nuts, though the thinned clusters may have slightly larger nuts. This also has been demonstrated on a whole tree scale with pruning experiments.

Blanking is more sensitive to insufficient irrigation than is splitting.

Effect of alternate bearing on blanking
Production of blank nuts is strongly affected by alternate bearing. As can be seen in Table 1, the percentage of blank nuts is always higher in the 'off' crop year. This is a further, though not proven, corroboration of the idea that the carbohydrate status of the tree entering a crop year sets the limits on the crop load a tree is able to set and carry through maturation to splitting. Markedly different crop loads within a given crop year (as shown in Table 1) had virtually the same percentage of blank nuts. For example, in 1989 the control trees with 0.2 pounds of crop per tree had 19.1% blanks, while the topped and hedged trees with 11.4 pounds of crop had 16.0% blanks. There was no statistically significant difference in these percentages despite the difference in crop loads. Plate 3A shows "on" and "off" current year pistachio shoots in mid July after axillary

flower bud abscission. The "on" year shoot is the one with nuts.

Conclusion

At present, there appears to be very little that can be done to affect the percentage of blanking. However, maintaining boron leaf levels above 120 ppm and providing sufficient water to avoid water stress during the season will at least avoid exacerbation of blank nut production.

NON SPLIT NUTS

The edible pistachio, unlike the species used for rootstocks, is characterized by splitting of the nut shell at maturity. Splitting begins about the end of July, at least one month before fruit maturity, and continues through mid-September, progressing simultaneously with nutmeat maturation. Final nutmeat maturity is indicated by separation of the hull from the shell. This is accompanied by a breakdown of chlorophyll pigments in the hull, allowing the red pigments to become visible. Thus, the most obvious indicator of shell splitting is the appearance of red color in the hull.

Pistachio nuts may split along the longitudinal ridges of the shell and at the tip of the shell. Splitting can occur in any combination of one or both of the longitudinal ridges, with or without the tip splitting, or at the tip alone. Investigation of the anatomical structure of the longitudinal and tip split regions indicates that these parts of the shell differ from one another structurally suggesting that different mechanisms may be involved in shell separation at each site.

Shell splitting is dependent upon nutmeat growth and development within the shell. Figure 3a shows the relationship between shell split and kernel growth. Note that kernel growth begins after the shell has reached its full size. The first split shells are seen about the time the kernel has grown to fill the shell and would be exerting physical pressure on it. At this time, the shell is fully lignified (hardened), and the cells that form the regions where longitudinal splitting will occur are dead. This fact would seem to rule out the possibility that biochemical factors are involved as a controlling mechanism in shell split making it unlikely that a chemical agent to enhance splitting will be discovered.
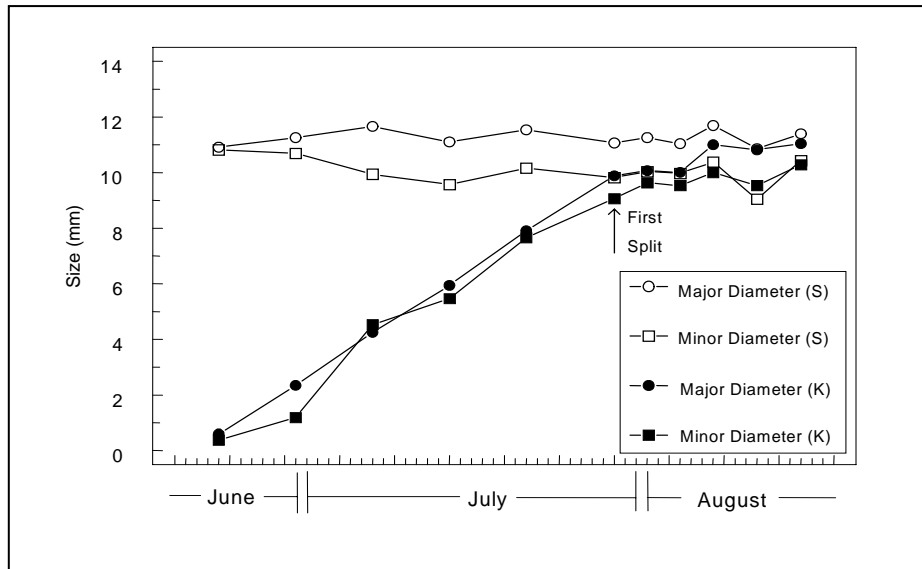

Figure 3a. This graph illustrates kernel and shell growth. The major (in the plane of the longitudinal split lines) and minor (perpendicular to the plane of the longitudinal split lines) diameters are shown. Data points represent means of 20 samples. The arrow indicates the time split shells were first seen in any nut (from Polito, V. S. and K. Pinney. 1999. Endocarp dehiscence in pistachio [*Pistacia vera* L.] Internat. J. Plant Sci. 160:827-835).

Table 1. Effect of 'on' and 'off' year versus individual tree crop load on the percentages of blank, split and non-split nuts (by weight).

Year & Treatment	Tree yield	Blank	Split	Non-Split
	lbs/tree	%	%	%
1985 'Off'				
Control	6.4 a	8.1 a	86.4 a	3.2 a
Hedge	4.6 b	7.2 b	86.1 a	3.0 a
Top	3.7 b	8.4 a	84.9 a	2.9 a
Hedge & Top	1.8 c	8.1 a	85.8 a	2.7 a
	Average	8.0	85.8	3.0
1986 'On'				
Control	49.2 a	2.1 a	63.4 a	30.4 a
Hedge	44.6 a	2.5 a	65.5 a	28.1 a
Top	39.9 b	2.9 a	64.2 a	30.1 a
Hedge & Top	28.1 c	2.6 a	62.5 a	29.4 a
	Average	2.5	63.9	29.5
1987 'Off'				
Control	3.5 c	10.1 ab	83.3 ab	3.7 a
Hedge	7.6 b	8.5 b	83.8 a	3.1 a
Top	11.7 a	11.5 a	80.3 b	3.7 a
Hedge & Top	14.2 a	10.2 ab	83.1 ab	3.6 a
	Average	10.1	82.6	3.5
1988 'On'				
Control	34.1 a	2.7 a	72.9 a	20.3 a
Hedge	26.3 b	2.8 a	72.6 a	21.3 a
Top	24.5 b	2.2 a	72.3 a	22.4 a
Hedge & Top	26.2 b	2.2 a	72.6 a	22.7 a
	Average	2.5	72.6	21.6
1989 'Off'				
Control	0.2 c	19.1 a	47.6 c	19.1 a
Hedge	0.6 c	17.7 b	61.2 b	13.5 c
Top	6.0 b	14.1 c	63.6 a	15.1 b
Hedge & Top	11.4 a	16.0 a	64.4 a	12.8 c
	Average	16.7	59.2	15.1
1990 'On'				
Control	37.1 a	11.2 a	67.5 a	21.1 a
Hedge	35.3 a	9.3 a	68.5 a	22.1 a
Top	30.4 b	11.7 a	63.5 a	22.8 a
Hedge & Top	27.2 b	13.8 a	67.4 a	18.7 a
	Average	11.5	66.7	21.2
1991 'Off'				
Control	3.0 c	19.2 a	59.0 a	21.1 b
Hedge	4.2 c	16.0 a	57.1 ab	26.0 b
Top	17.2 b	15.1 a	50.1 bc	34.0 a
Hedge & Top	25.8 a	17.0 a	47.1 c	35.1 a
	Average	16.8	53.3	29.1

* Values within a crop year column followed by the same letter are statistically equal.

There is a correlation between kernel-to-shell size ratios and longitudinal splitting. Table 2 shows the relationship of kernel diameters to inner shell diameters for six samples of undried, filled nuts. In each case, the ratio of kernel to shell size is greater for fully split nuts than it is for tip-split or unsplit nuts. Interestingly, there is no statistical difference between tip-split and unsplit nuts, a finding that is consistent with anatomical indications that tip split and longitudinal split involve different mechanisms. Furthermore, for fully split nuts, the kernel-to-shell diameter ratios in the minor axis, i.e. perpendicular to the plane of the longitudinal ridges, is consistently greater than one. This means that for fully split nuts, kernel size is greater than shell size in the direction where force against the inside of the shell would tend to drive the shell halves apart. These correlations would seem to implicate mechanical force generated by the growing kernel against the shell as the mechanism for shell splitting. It should be noted, however, that experimental evidence to verify this inference is lacking.

Table 2. Ratio of kernel to shell (K:S) diameters for undried, filled nuts. Nuts were considered in three categories: nuts that had split fully along both longitudinal ridges, nuts that had split at the tip of the shell only, and nuts with unsplit shells. Ratios are for kernel diameter and shell inner diameter at their widest point. The major diameter is in the plane parallel to the longitudinal ridges; the minor diameter is in the plane perpendicular to the longitudinal ridges. For each sample n = 20; samples 4 through 6 had fewer than 20 tip-split nuts. For each diameter ratio for each sample, values with different letters differ significantly (P <0.05).

Sample	Major Diameter (K:S Ratio)			Minor Diameter (K:S Ratio)		
	Full Split	Tip Split	Unsplit	Full Split	Tip Split	Unsplit
1	0.97 a	0.90 b	0.89 b	1.06 a	0.90 b	0.96 b
2	0.98 a	0.85 b	0.85 b	1.07 a	0.90 b	0.90 b
3	0.95 a	0.88 b	0.83 b	1.06 a	0.94 b	0.92 b
4	1.02 a	--	0.90 b	1.10 a	--	0.97 b
5	0.94 a	--	0.83 b	1.02 a	--	0.88 b
6	0.97 a	--	0.81 b	1.02 a	--	0.90 b

If it is the growth of the kernel that drives shell split, then factors that enhance kernel size relative to shell size would lead to more split nuts. Crop load is one such factor; irrigation management is another. Both can affect the percentage of split nuts.

There is an inverse relationship between tree crop load, the percentage of nuts with split shells, and the percentage of blank nuts (Table 1). As crop load increases, the percentage of nuts with split shells decreases, and the percentage of blank nuts decreases. Thus, in 'heavy' crop years the marketable crop is decreased by non-splits, and in 'light' crop years it is decreased by blanks. Further, it is interesting to note that the percentage of non-split nuts and blanks is much more strongly correlated with the 'heavy' and 'light' crop year than with individual tree crop load. A review of the seven years of crop production in trees with altered crop loads in Table 1, shows that only when the crop load is as little as 0.2 pounds per tree versus 11.4 pounds per tree (1989), or 3.0 versus 25.8 pounds per tree (1991), are significant differences produced in the percentage of split shells. This suggests that the ability of the tree to support and mature a crop is a stronger factor in determining the percentage of splitting than the actual pounds of crop on the tree in any given season.

Effects of female cultivar, pollen source and rootstock on shell splitting

Research within the past 20 years has demonstrated the effects of scion cultivar and pollen source, but not thus far of rootstock, on

pistachio nut shell splitting. First, it is well established that variability in shell splitting exists among edible pistachio cultivars. This is one of the primary selection criteria for new cultivars and was among those for the selection of 'Kerman'. Second, research demonstrated pollen from 'Peters' and 'Ask' male trees produced a higher percentage of split nut shells than pollen from 'Atlantica' males. There is no evidence that different rootstocks producing differences in shell splitting. In rootstock trials currently being conducted in California, no significant differences in shell splitting percentages have been detected among *P. atlantica*, *P. integerrima* and the hybrids of these two rootstocks.

Effects of preharvest production practices on shell splitting

Certain field production practices do affect shell splitting. In decreasing order of degree of impact, these factors are: harvest time, irrigation management, boron nutrition and dormant pruning.

There are research results that show the highest shell split percentages are achieved when harvest is delayed until the maximum number of nuts display hull dehiscence, or separation, from the nut shell. Dehiscence is signaled primarily by a hull color change to red. In practice, progress of hull dehiscence is evaluated by observing the early color change in the hulls and, at that time, randomly sampling trees for split nuts. Specifically, collect a 100-nut sample from around the tree, remembering those in the upper southwest quadrant will mature first, and determine the percentage of nuts on which the hull is easily removed and the shell is split. Do this daily until the increase in the percentage of split nuts appears to be slowing. However, this period of maximum nut shell splitting must also be balanced against the threat of navel orangeworm (NOW) infestation, (the possibility of a spray with a preharvest interval), as well as the availability of harvesting machinery. Delaying harvest until maximum nut shell splitting percentages are achieved may result in NOW infestation and shell staining.

Additional research has demonstrated insufficient irrigation from mid-August through early September will significantly decrease the percentage of split nuts. Further, preliminary data currently being generated suggests that regulated deficit irrigation from mid-May through the end of June may increase the percentage of shell splitting.

Studies showed that a late dormant spray of 2-5 pounds of Solubor per acre, applied at budswell, will significantly increase the percentage of split nut shells. This can be tank mixed with the late dormant zinc spray.

Dormant pruning has a negligible effect on the percentage of splits. The alterations in yield presented in Table 1 were produced by dormant pruning. From this data, it can be seen that only when dormant pruning produced differences in crop load per tree that varied significantly were there significant differences in the percentage of splits, as in 1989 and 1991. Further, these differences were produced by pruning treatments done four and seven years earlier. Later research demonstrated approximately half a pistachio tree's fruit buds can be removed, and the tree will compensate by setting more nuts per cluster with the same percentage of split nuts as the unpruned controls. Thus, dormant pruning has a limited effect on shell splitting; unless the pruning is quite severe, it does not impact tree crop load, and therefore will not impact shell splitting. Further, as discussed previously, shell splitting appears to be more responsive to 'on' and 'off ' crop year than individual tree crop load.

Thus far, no information has been generated in California demonstrating the effects of irrigation water quality on shell splitting. Thus, it is not ranked in the production practices discussed here. However, preliminary information is available from Israel that irrigation water salinities of 4,000 mg/liter of total soluble solids (TSS), primarily sodium (Na) and chlorine (Cl), have decreased shell splitting. Currently, rootstock trials are in progress in California to determine the relative salinity tolerance of *P. atlantica* and *P. integerrima* and the two hybrids of these two rootstock species, to salinities ranging from ECws of 0.75 through 8.0.

Effects of postharvest factors on shell splitting

No postharvest practice has yet been demonstrated to significantly impact the percentage of split pistachio nut shells. However, pistachio shells have a high percentage of moisture. Anytime the harvested pistachio nut is subjected to heat, during postharvest transport, preprocessing waits and drying, this heat will decrease the moisture content of the shells, literally shrinking the shell about the nut and increasing the width of the split. Thus, pistachios can leave the field with a lower percentage of wide splits than they have when they arrive at the processor. During processing, this increase in split width occurs very early in drying and increases as dryer temperatures increase from $125^{o}F$ to 190 ^{o}F. This increase can result in nut kernels dropping out of the shell.

Conclusion

Controllable factors that affect shell split include: harvest timing, irrigation and boron nutrition. To obtain the best percentage of split shells with the 'Kerman' female and 'Peters' male cultivars: harvest timing should be based upon the appearance of hull color and a sampling for the percentage of splits. Trees should not be water stressed from mid-August through September; and boron levels should be maintained above 120 ppm by dry weight of July leaf sample. Hopefully, through the long-term rootstock evaluation, and cultivar and rootstock breeding program in progress, information concerning the effects of rootstock and salinity on shell splitting, as well as new female cultivars and male pollinizers, will be available in the next few years.